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STABILITY AND CONTROL CHARACTERISTICS AT
A MACH NUMBER OF 1.89 OF A LIGHTWEIGHT GLIDER
REENTRY CONFIGURATION

By Ross B. Robinson and M. Leroy Spearman

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Langley Field, Va.

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WASHINGTON May 1960

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORAUNDUM X-276

STABILITY AND CONTROL CHARACTERISTICS AT A MACH NUMBER OF 1.89 OF A LIGHTWEIGHT GLIDER REENTRY CONFIGURATION*

By Ross B. Robinson and M. Leroy Spearman

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SUMMARY

An investigation has been made in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 1.89 to determine the stability and control characteristics of a lightweight glider reentry vehicle for flight attitudes corresponding to conventional flight in the atmosphere at relatively low angles of attack. The configuration investigated was an all-wing design with a diamond plan form. A small fuselage was located on the top side of the wing, and twin ventral fins were attached to the lower side of the wing.

The results indicated that the configuration was stable both longitudinally and directionally. The presence of twin ventral fins that were inclined to the body center line caused a negative increment in pitching moment throughout the lift range and also reduced the maximum value of lift-drag ratio considerably. The maximum trimmed value of lift-drag ratio was about 4.2.

INTRODUCTION

Among the vehicles being considered for winged reentry into the earth's atmosphere are lightweight glider arrangements that provide extremely low wing loadings and high values of lift-drag ratio. At high altitude such vehicles would operate at high angles of attack to reduce their speed before entering the lower atmosphere. Subsequent to reentry the vehicle would perform a transition to a conventional flight attitude and, for the remainder of its flight, would operate in a manner similar to that of a conventional airplane.

*Title, Unclassified.

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As a part of a general study of such reentry vehicles, an investigation has been made in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 1.89 to determine the stability and control characteristics of a representative lightweight glider-type reentry machine for conventional flight attitudes. The configuration investigated was an all-wing design with a diamond plan form. The trailing-edge portions of the wing were used as elevons to provide longitudinal and lateral control. A small fuselage was located on the top side of the wing and twin directional stabilizing surfaces were attached to the lower side of the wing. The results of the investigation are presented herein.

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SYMBOLS

The results are referred to the body axis system except the lift and drag coefficients which are referred to the stability axis system. The moment-reference point is at a longitudinal station corresponding to the 71.2-percent body length and at a vertical station 0.625 body diameters below the body center line. (See fig. 1.)

C_D drag coefficient, F_D/qS

C_L lift coefficient, F_L/qS

C_l rolling-moment coefficient, M_X/qSb

C_m pitching-moment coefficient, $M_Y/qS\bar{c}$

C_n yawing-moment coefficient, M_Z/qSb

C_Y side-force coefficient, F_Y/qS

F_D drag force

F_L lift force

F_Y side force

M_X rolling moment, moment about X-axis

M_Y pitching moment, moment about Y-axis

M_Z	yawing moment, moment about Z-axis
q	free-stream dynamic pressure
S	wing area, including fuselage intercept and elevons
$\bar{c}$	wing mean geometric chord
b	wing span
M	free-stream Mach number
L/D	lift-drag ratio, C_L/C_D
C_{l_β}	effective-dihedral parameter
C_{n_β}	directional-stability parameter
C_{Y_β}	side-force parameter
X,Y,Z	body axes system
α	angle of attack, deg
β	angle of sideslip, deg
δ	elevon deflection, both elevons unless noted, positive trailing edge down, deg

Components:

B	body
W	wing
V	ventral fins
E	elevons
L	left elevon
R	right elevon

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MODELS AND APPARATUS

Details of the model are shown in figure 1, and a photograph of the model is presented as figure 2. The wing and vertical-tail (ventral fin) surfaces had flat-plate sections with beveled edges. Deflections of the elevons were obtained through the use of preset deflection plates. The ventral fins, which were attached to the inboard edge of the elevons, were inclined to the body center line and, therefore, presented some frontal area as well as side area. Since the ventral fins were attached to the elevons, they moved as the elevons were deflected.

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A body that enclosed a six-component strain-gage balance was attached to the upper side of the wing. The model was mounted in the tunnel on a remotely controlled rotary sting in order to facilitate testing at combined angles of attack and sideslip.

TESTS, CORRECTIONS, AND ACCURACY

The test conditions were as follows:

Mach number	1.89
Stagnation temperature, $^{\circ}$F	65 to 90
Stagnation pressure, lb/sq ft	285
Reynolds number, based on $\bar{c}$	0.43×10^6 to 0.39×10^6

The stagnation dewpoint was maintained sufficiently low (-25° F or below) so that no condensation effects were encountered in the test section.

Tests were made through an angle-of-attack range from about -2° to 20° at $\beta = 0^{\circ}$ and through a sideslip range from -2° to 10° at nominal angles of attack of -0.3°, 8.4°, 12.6°, and 16.9°.

The angles of attack and sideslip were corrected for the deflection of the balance and sting under load. The base pressure was measured, and the drag force was adjusted to a base pressure equal to free-stream static pressure.

The estimated accuracy of the individual quantities is as follows:

C_D	± 0.0014
C_L	± 0.0015
C_l	± 0.0001

[redacted]

C_m	±0.0005
C_n	±0.0001
C_Y	±0.0010
M	±0.015
α, deg	±0.2
β, deg	±0.2
δ, deg	±0.2

DISCUSSION

Longitudinal Stability and Control

The aerodynamic characteristics in pitch for various combinations of component parts are presented in figure 3. The addition of the elevons to the body wing provides a substantial margin of longitudinal stability, and the pitching-moment characteristics indicate a slight increase in stability with increasing lift. The addition of the ventral fins had no effect on the longitudinal stability characteristics. However, because of the positive lift increment induced by the fins and, to some extent, because of the drag force acting on the projected frontal area of the fins, the addition of the fins caused a negative increment in pitching moment throughout the lift range. The effect of this added increment of pitching moment is to increase the amount of control required for trimming. In addition, the presence of the inclined fins causes a substantial reduction in the maximum value of L/D (from 6.3 to 4.4).

Deflection of the elevons (fig. 4) has little effect on the stability level and provides reasonably linear increments of lift and pitching moment. With increasing negative deflection of the elevons, the minimum drag first decreases and then increases. This is a result of the drag contribution of the ventral fins that are attached to the elevons. For small negative deflections of the elevon, the minimum drag is reduced because of a decrease in the fin drag. For larger negative deflections, the drag increment of the elevon dominates.

The longitudinal-trim results (fig. 5) indicate linear control characteristics and a maximum trimmed value of L/D of about 4.2 for the moment-center location used.

Lateral and Directional Stability

The effects of ventral fins on the sideslip characteristics are presented in figure 6, and the sideslip derivatives are summarized in

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figure 7. The addition of the ventral fins provides a negative increment of C_{Y_β} as would be expected. (See fig. 7.) This side force provides a directionally stable configuration with an essentially constant value of C_{n_β} up to $\alpha \approx 12^{\circ}$.

The addition of the ventral fins has little effect on C_{l_β}, however, and the indication is that the positive increment in roll to be expected from the fins is offset by a change in wing lift (and rolling moment) due to the fin pressure fields.

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Lateral Control

A limited study of the roll-control characteristics was made by deflecting only the left elevon. The results (fig. 8) indicate an essentially constant increment of rolling moment throughout the angle-of-attack range investigated. Although a large adverse yawing moment is indicated, this would be offset to some extent through opposite deflection of the right elevon.

CONCLUDING REMARKS

An investigation has been made in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 1.89 to determine the stability and control characteristics of a lightweight glider reentry vehicle for flight attitudes corresponding to conventional flight in the atmosphere at relatively low angles of attack.

The results indicated that the configuration was stable both longitudinally and directionally. The presence of twin ventral fins that were inclined to the body center line caused a negative increment in pitching moment throughout the lift range and also reduced the maximum value of lift-drag ratio considerably. The maximum trimmed value of lift-drag ratio was about 4.2.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., January 7, 1960.

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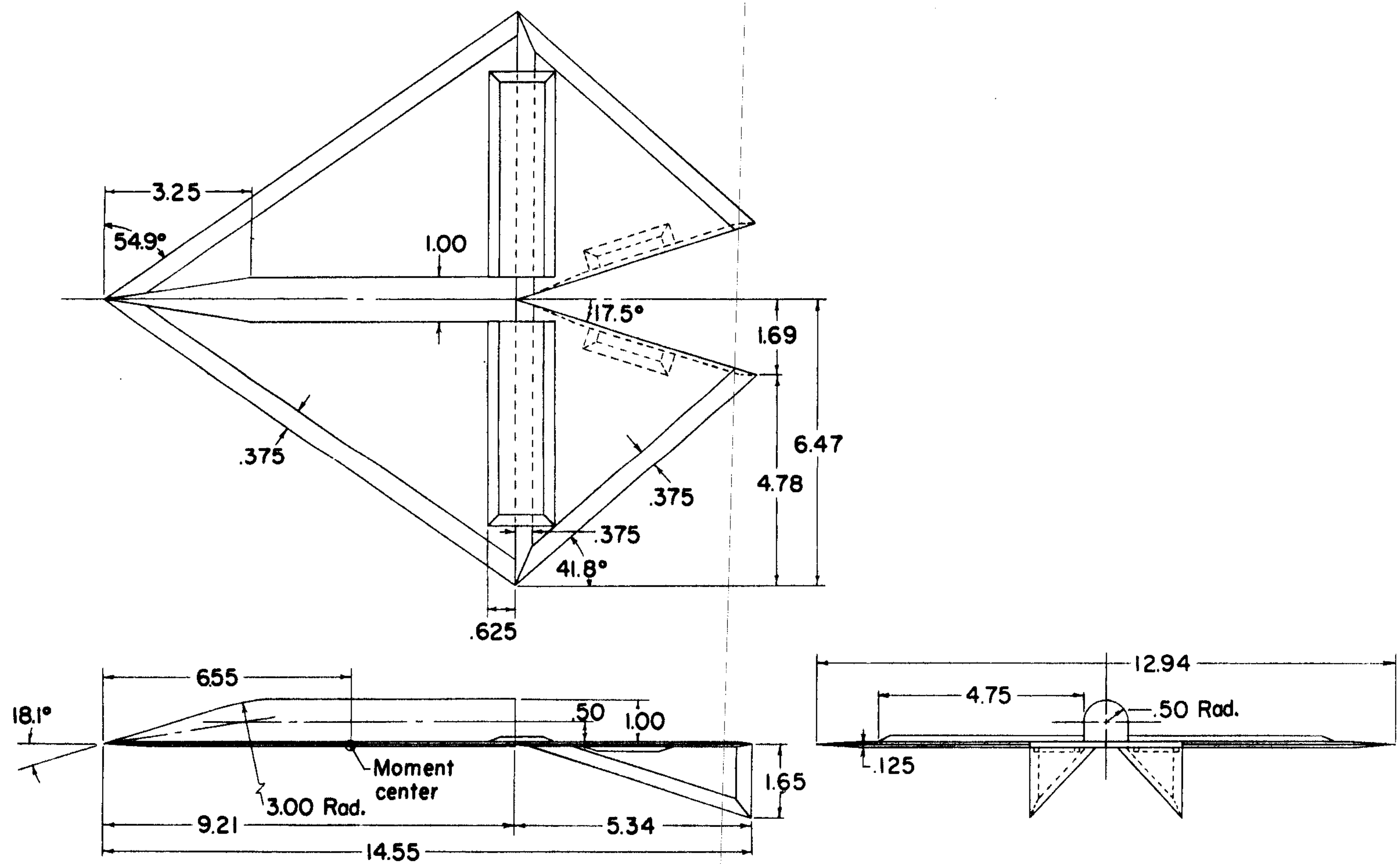

Figure 1.- Details of model. All linear dimensions are in inches.

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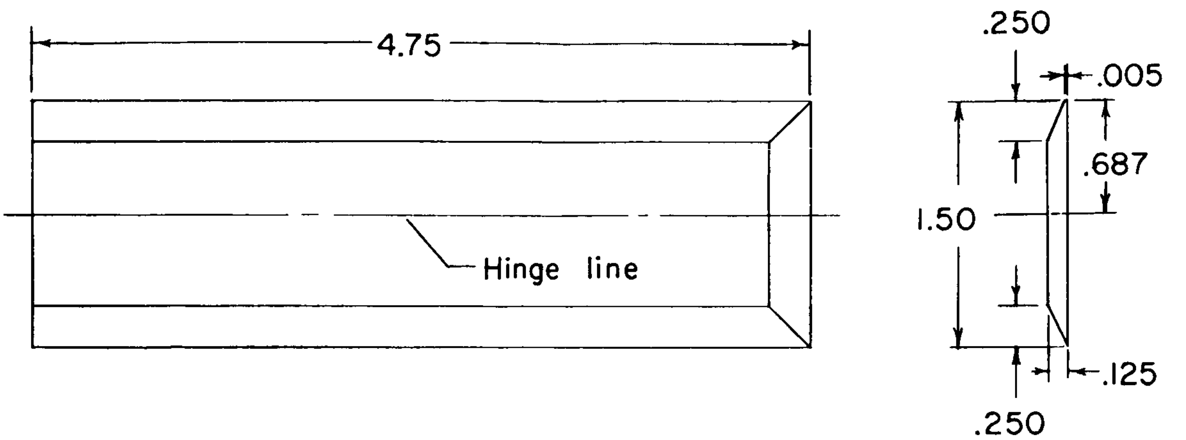
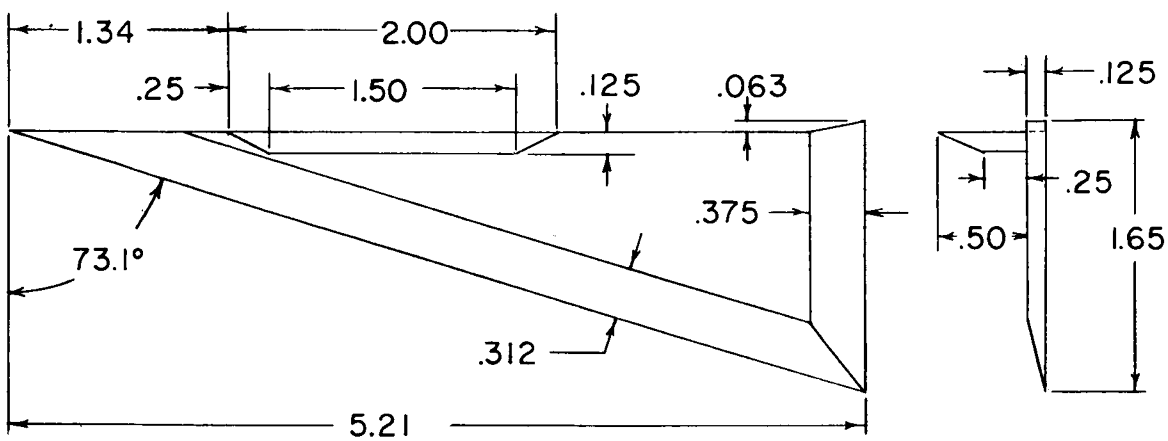


Right-elevon deflection plate



Ventral fin

Figure 1.- Concluded.

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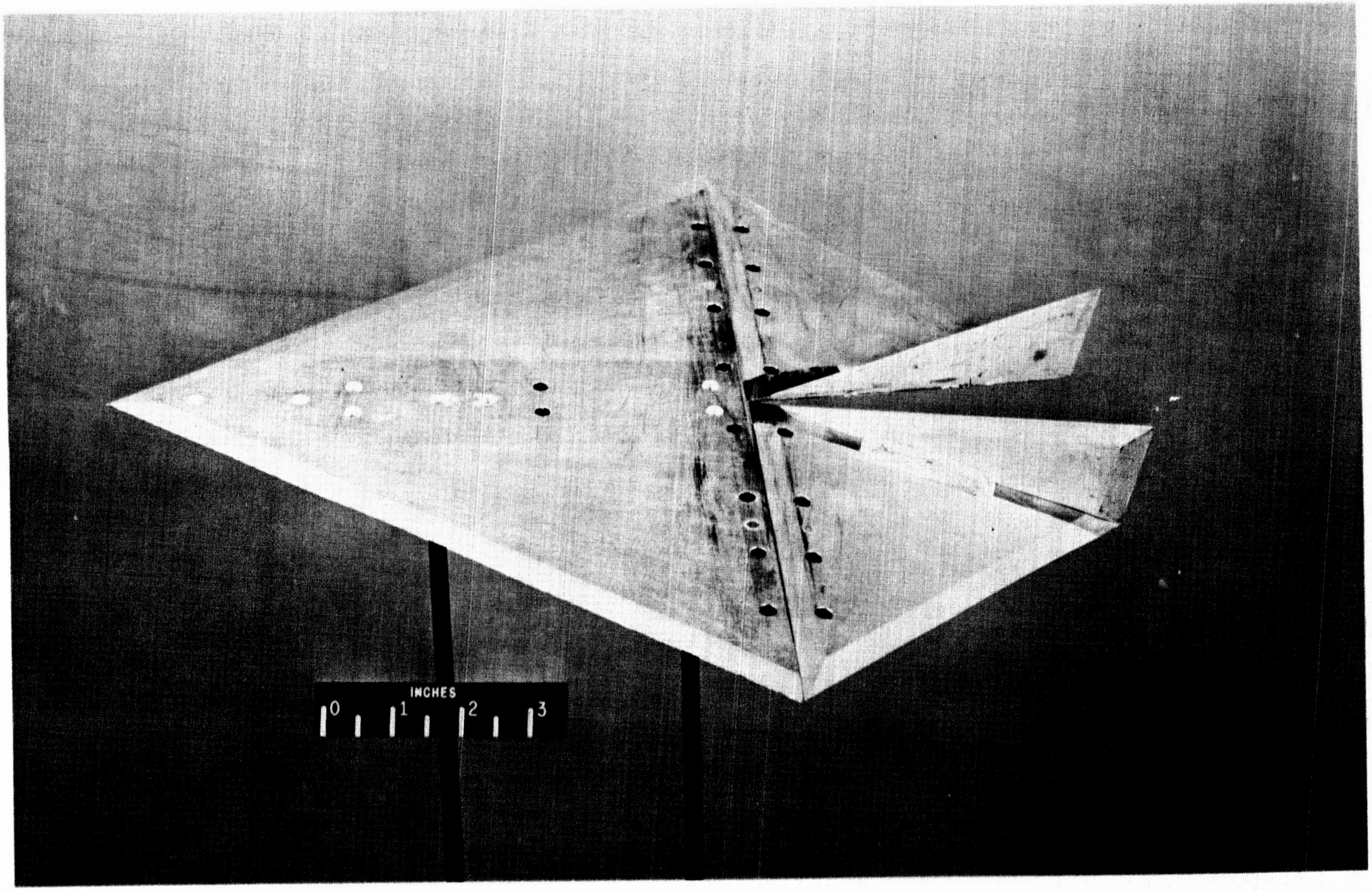

Figure 2.- Photograph of complete configuration in inverted position. L-59-3382

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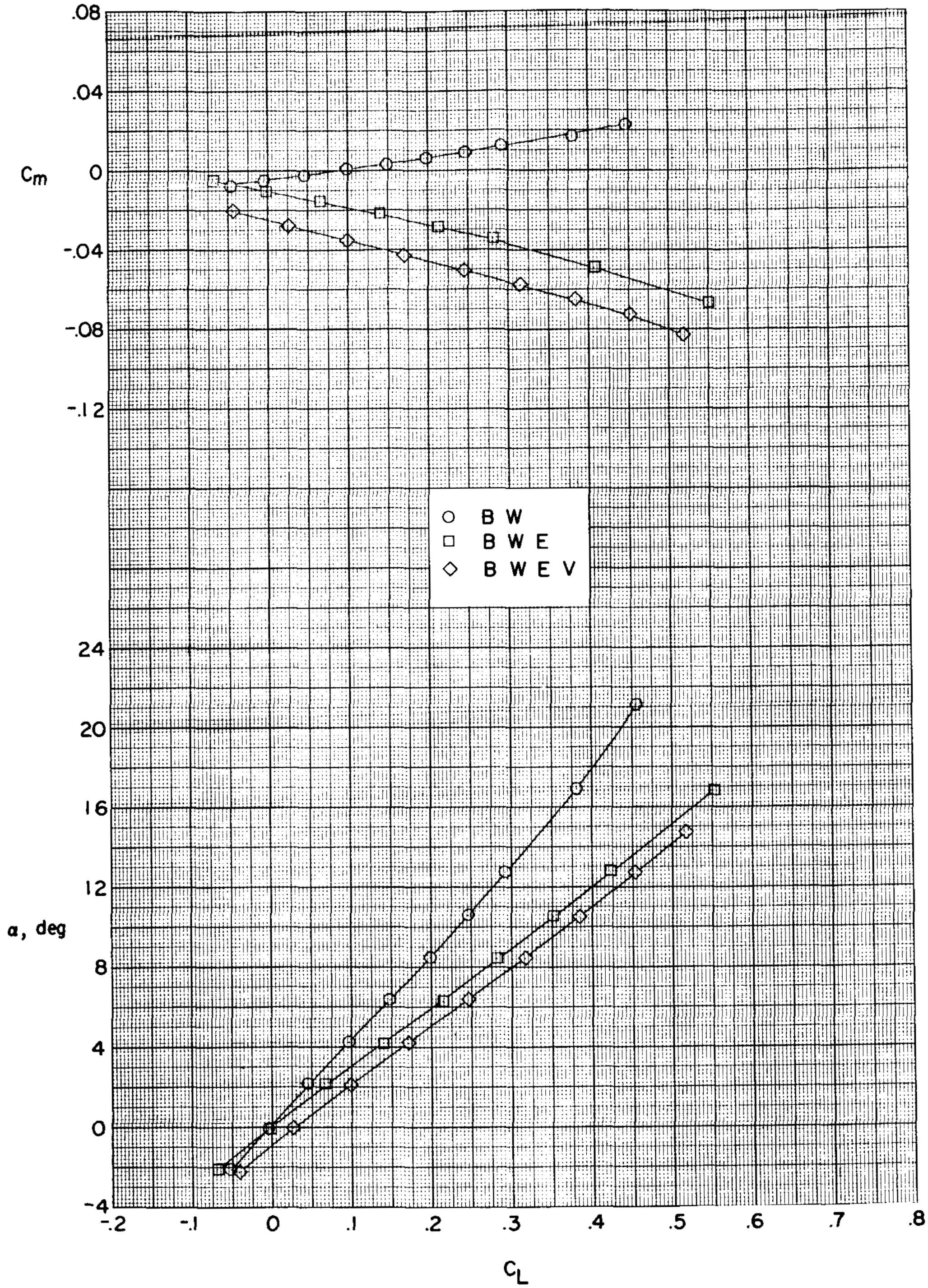

Figure 3.- Aerodynamic characteristics in pitch for various combinations of component parts.

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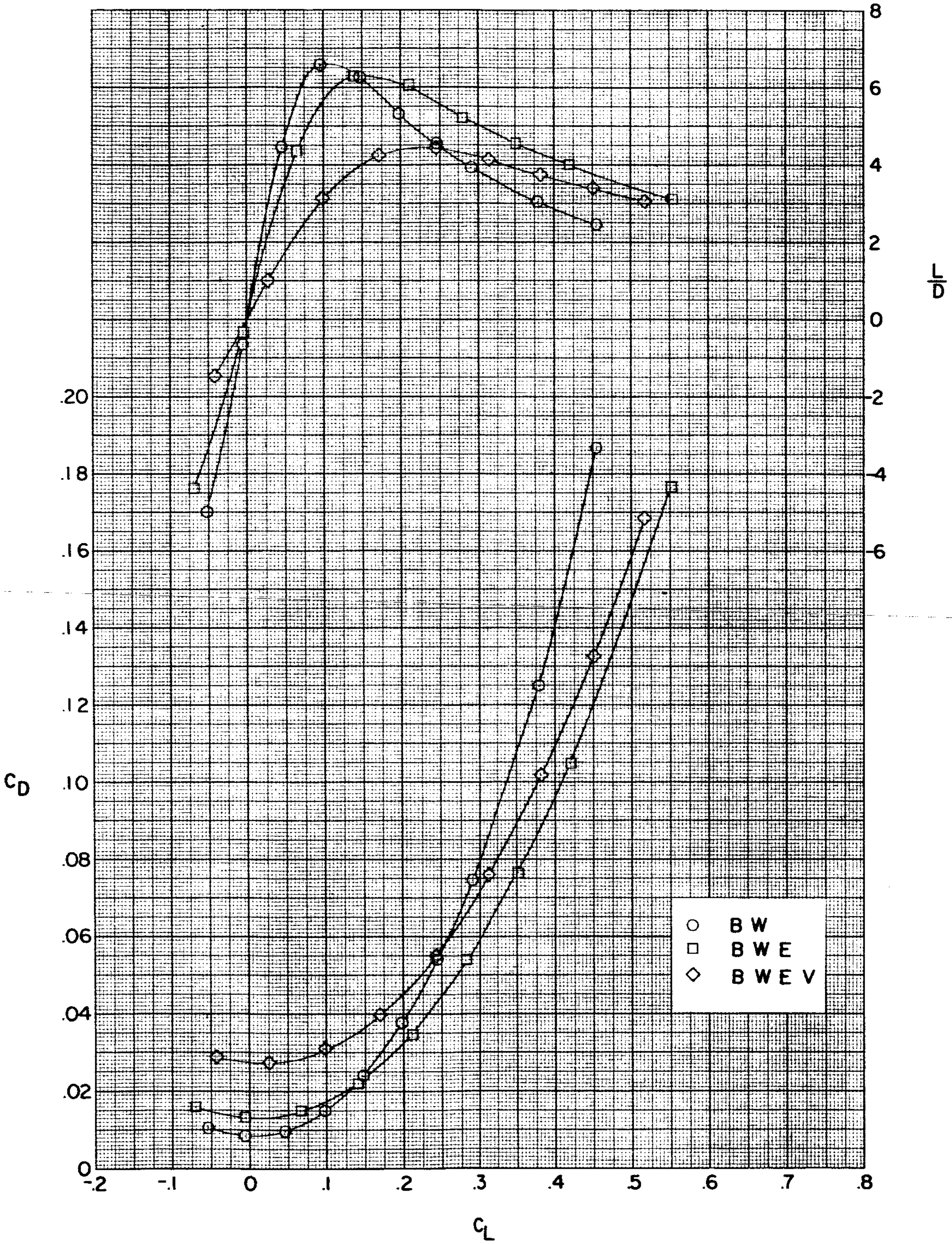

Figure 3.- Concluded.

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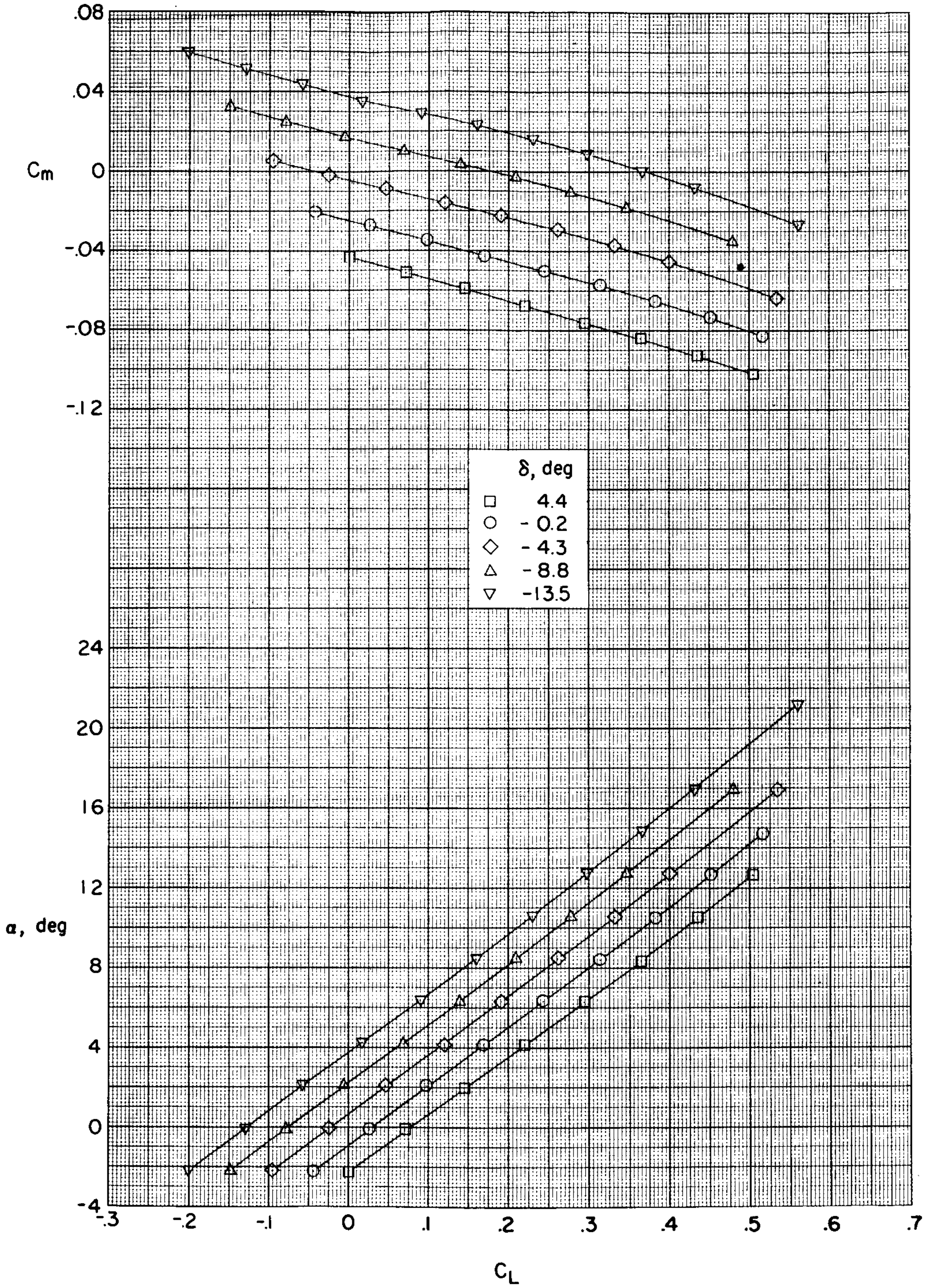

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Figure 4.- Effect of elevon deflection on the aerodynamic characteristics in pitch; complete model.

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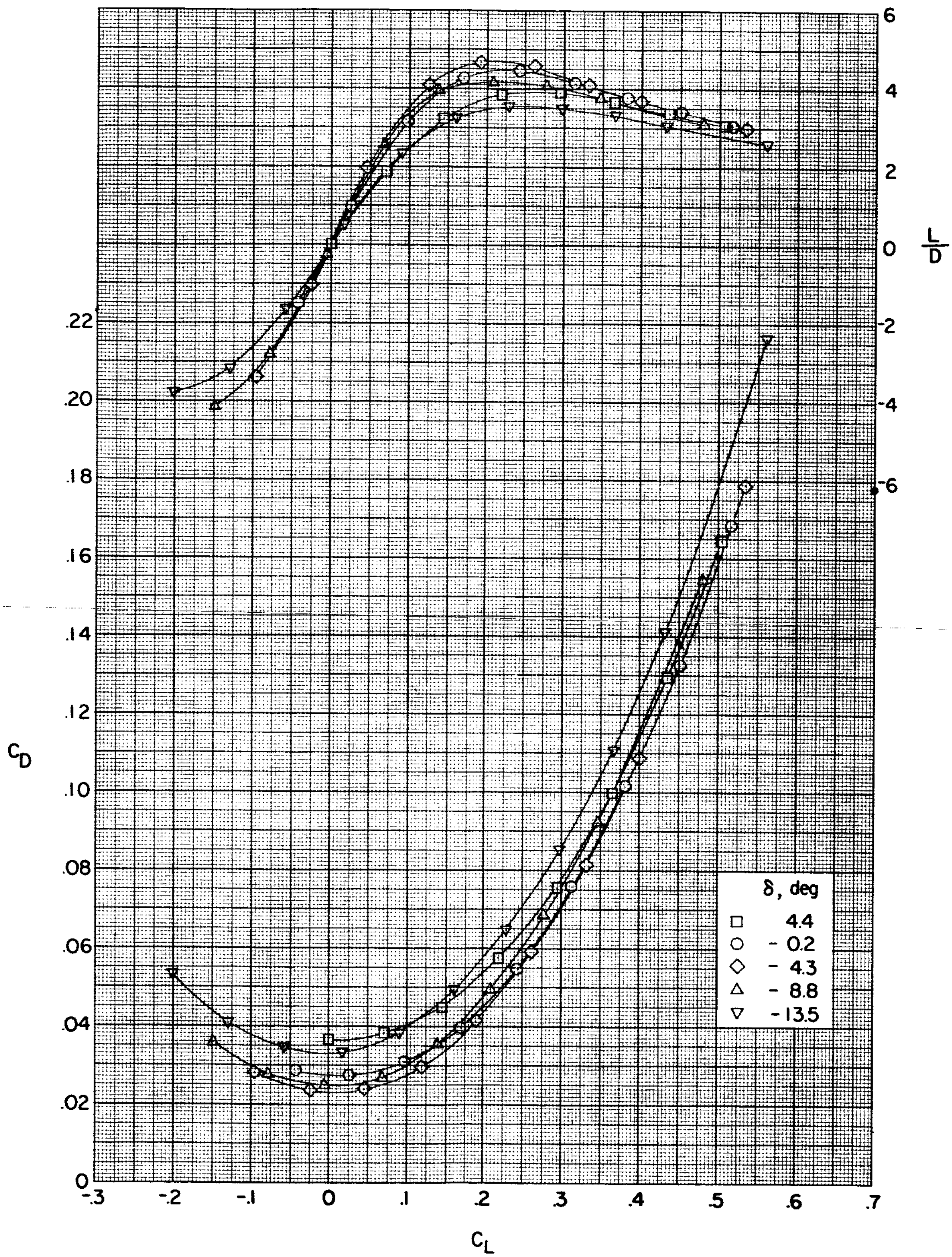

Figure 4.- Concluded.

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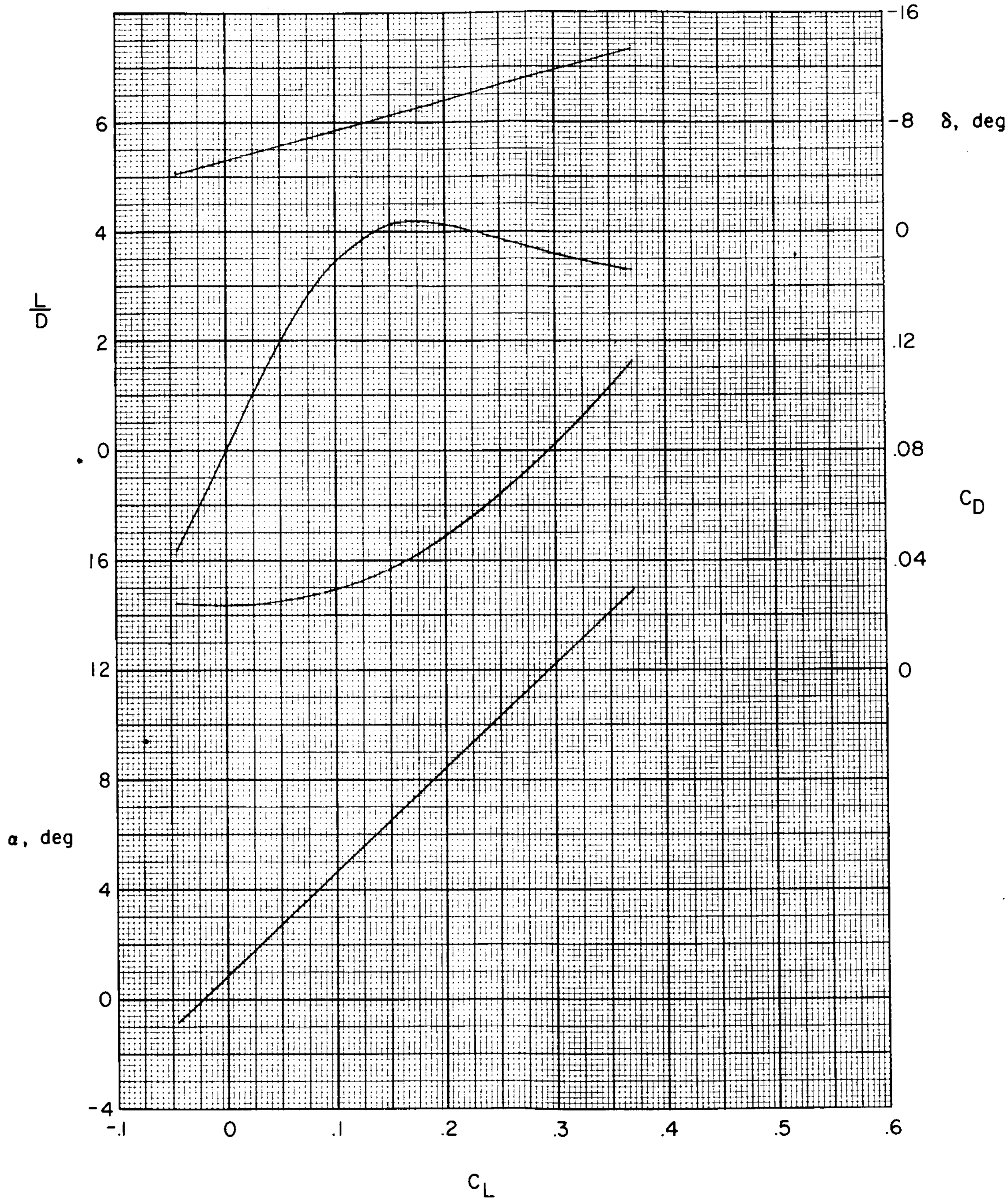

Figure 5.- Longitudinal-trim characteristics; complete model.

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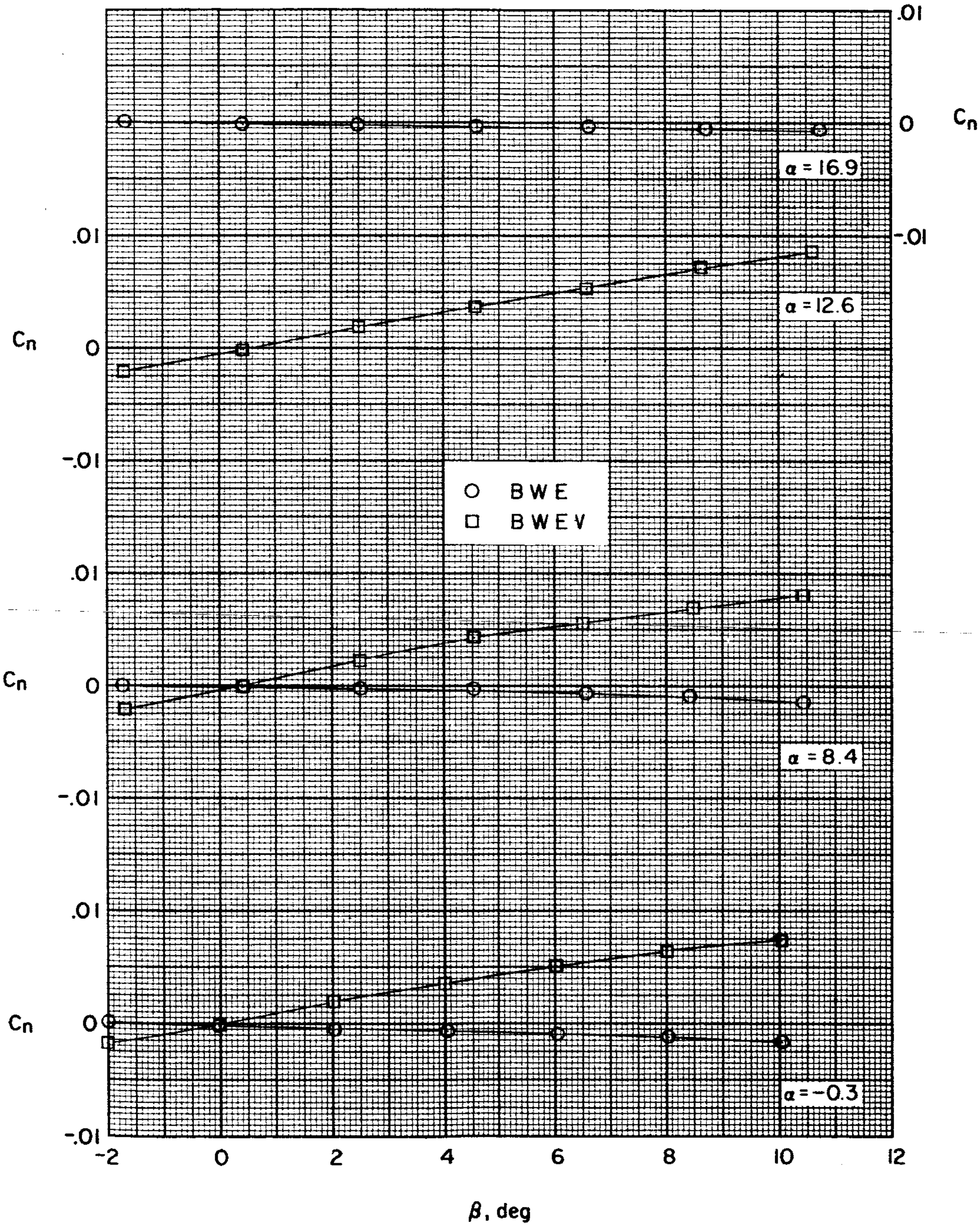

(a) Variation of C_n with β.

Figure 6.- Effect of ventral fins on the aerodynamic characteristics in sideslip; $\delta = -0.2^{\circ}$.

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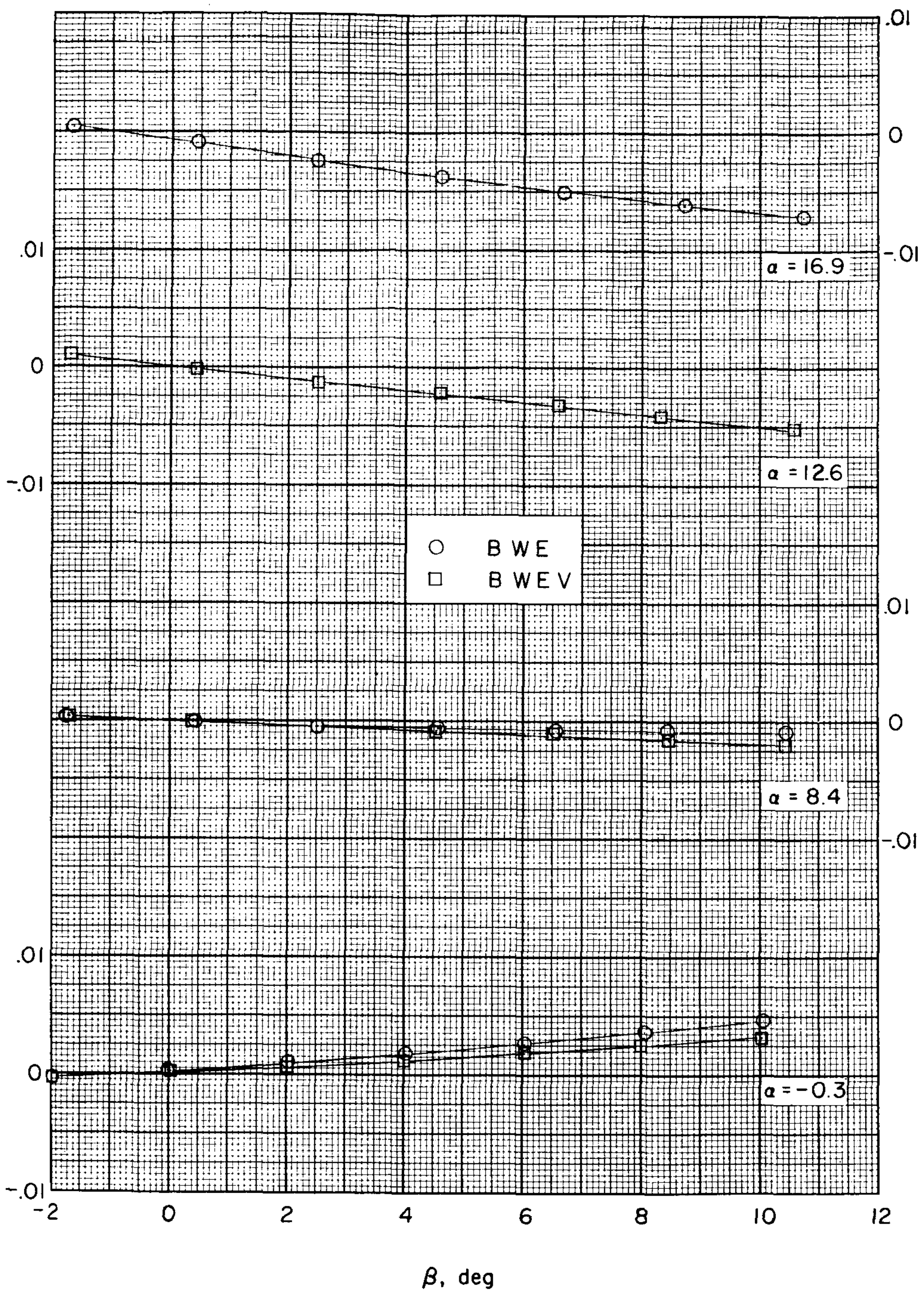

(b) Variation of C_l with β.

Figure 6.- Continued.

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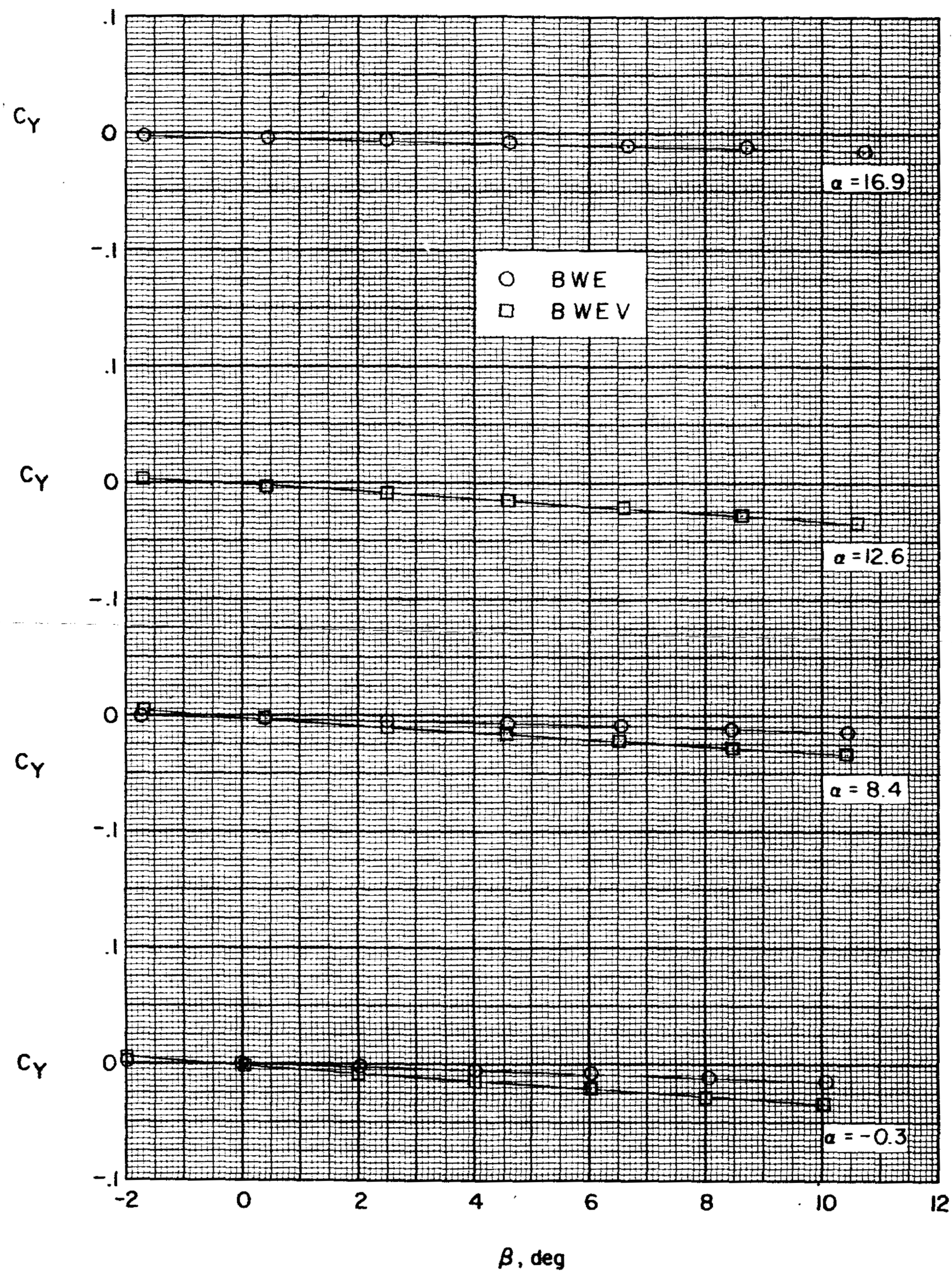
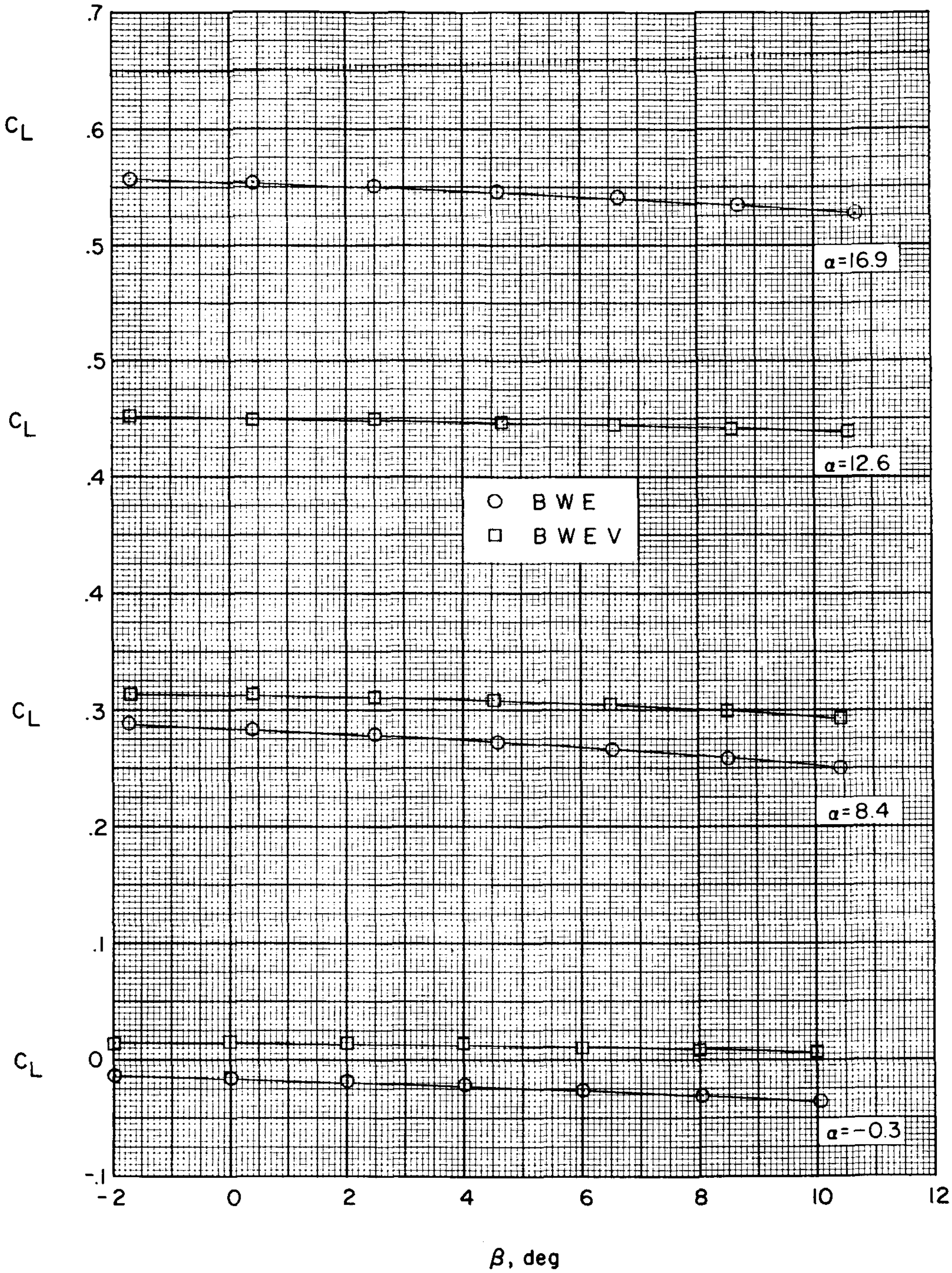


(c) Variation of C_Y with β.

Figure 6.- Continued.



(d) Variation of C_L with β.

Figure 6.- Continued.

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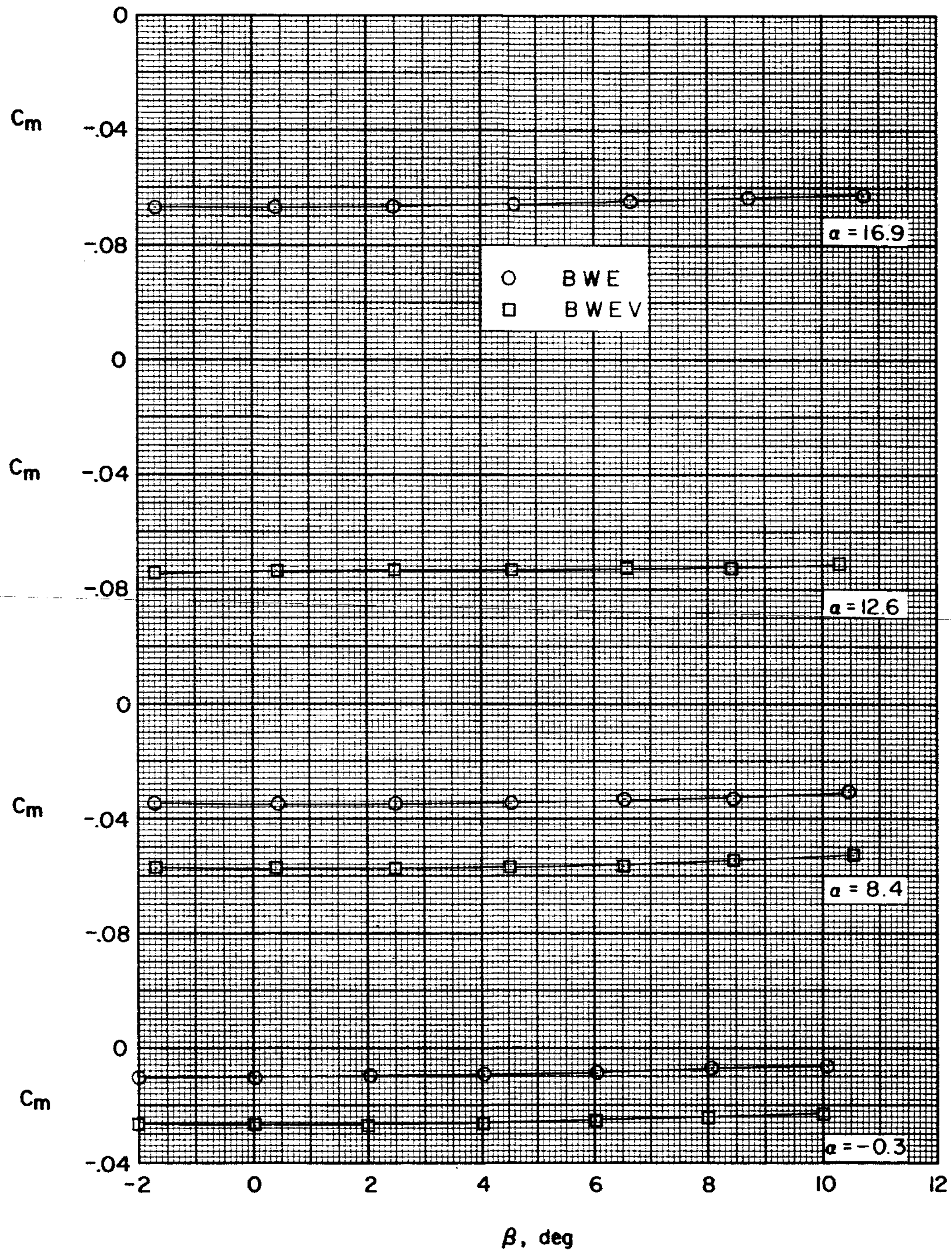

(e) Variation of C_m with β.

Figure 6.- Concluded.

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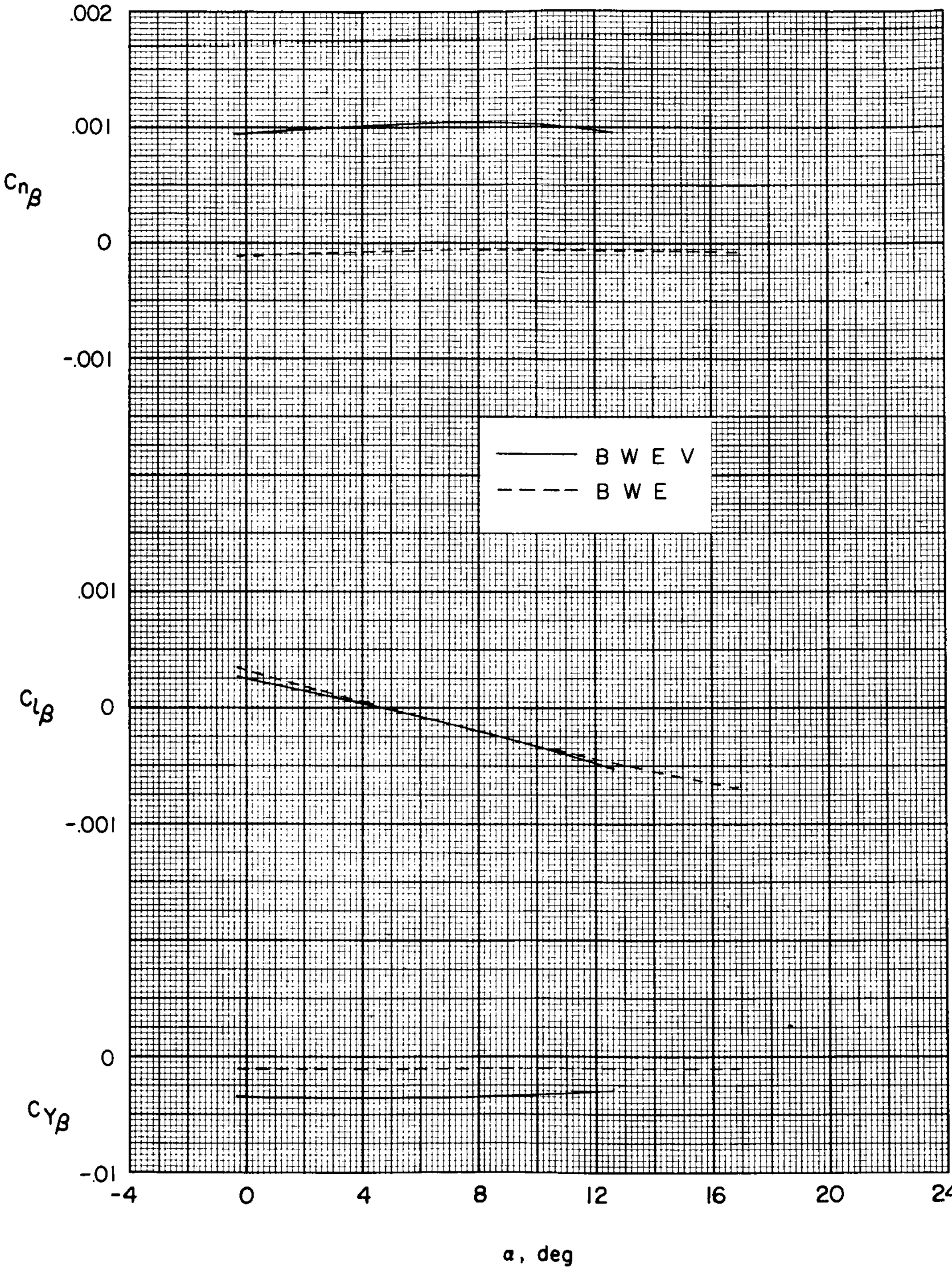

Figure 7.- Effect of ventral fins on the lateral characteristics; $\delta = -0.2^{\circ}$.

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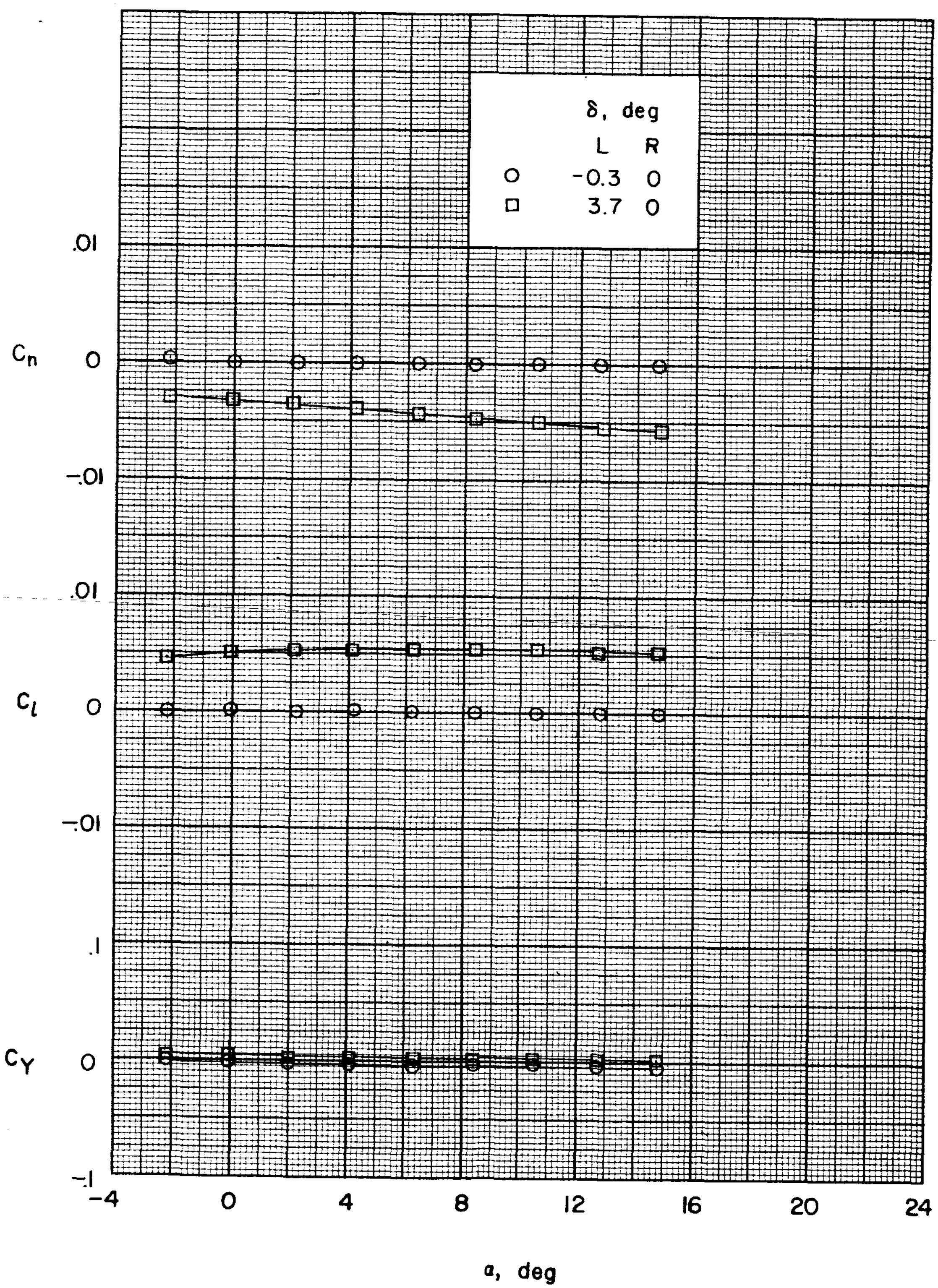

Figure 8.- Roll-control characteristics; complete model.

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